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Airborne and Ground-Based Optical Characterization of Legacy Underground Nuclear Test Sites

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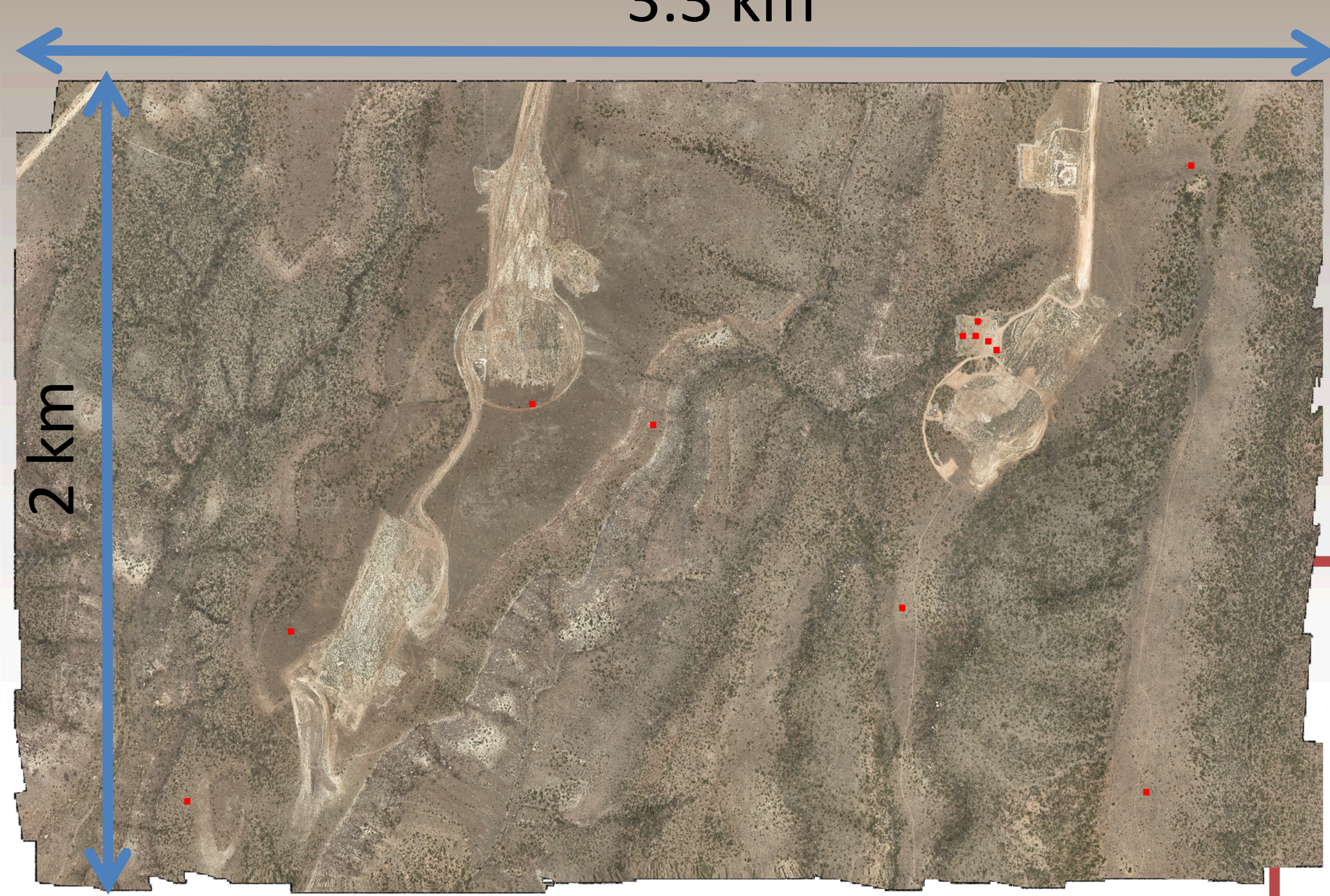
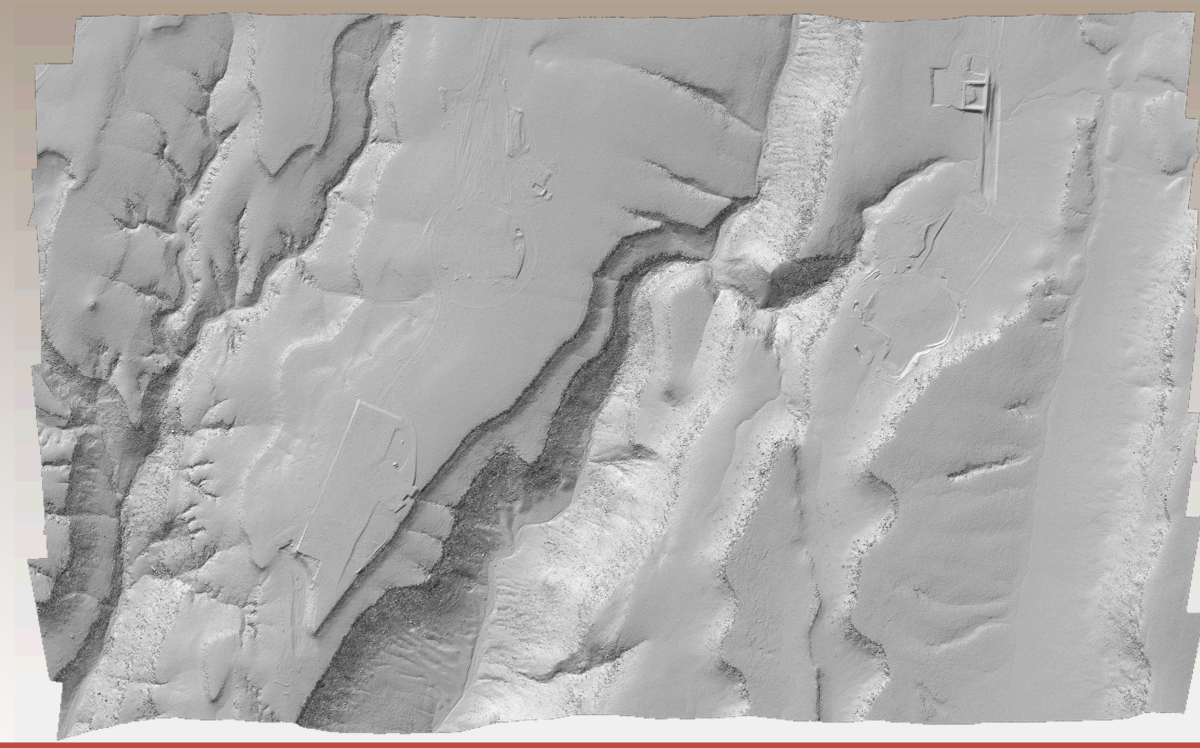
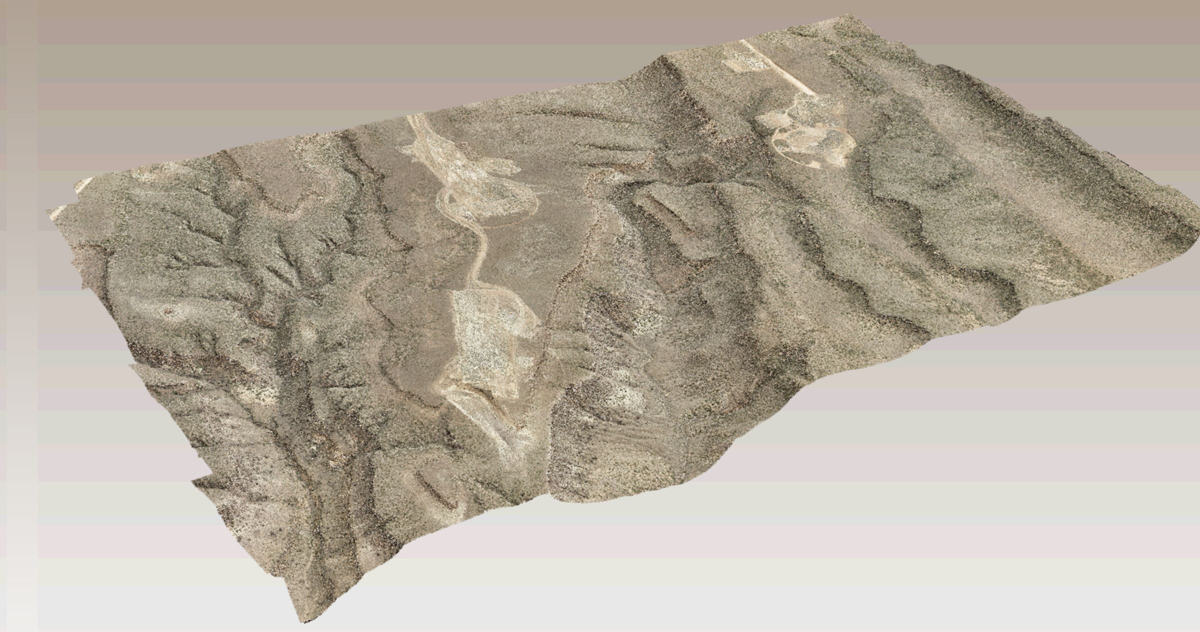
Abstract
Detecting, locating, and characterizing suspected underground nuclear test sites is a priority for the U.S. Currently, global underground nuclear explosion monitoring relies on seismic and infrasound sensor networks to provide rapid initial detection of potential underground nuclear tests. While seismic and infrasound might be able to generally locate potential underground nuclear tests, additional sensing methods might be required to further pinpoint and characterize test site locations. Optical remote sensing is a robust approach for site location and characterization due to the ability it provides to search large areas relatively quickly, resolve surface features in fine detail, and perform these tasks non-intrusively. Optical remote sensing can provide both cultural and surface geological information about a site, for example, operational infrastructuresurface fractures. Surface geological information, when combined with known or estimated subsurface geologic information, could provide clues concerning test parameters. We have characterized two legacy nuclear test sites on the Nevada National Security Site (NNSS), U20ak and U20az using helicopter-, ground- and unmanned aerial system-based RGB imagery and light detection and ranging (lidar) systems. The multi-faceted information garnered from these different sensing modalities has allowed us to build a knowledge base of how a nuclear test site might look when sensed remotely, and the standoff distances required to resolve important site characteristics.

Project Overview
Field operations were conducted at the NNSS in early December, 2014 (rotor-based lidar and photogrammetric imaging) and June, 2015 (UAS-based photogrammetric imagery). The survey utilized ground control placed throughout the collection area for the purposes of these collection missions (see RGB mosaic) and simultaneous GPS observation at an onsite base station during the collect. The lidar/photogrammetric collect is a traditional collection methodology and provides a performance baseline against which other collection methods can be evaluated. The UAS-based collect was performed to test emerging collection capabilities enabled by comparatively simple, yet robust, UAS platforms. The UAS collection methodology utilized the custom-built Silent Falcon™ airframe provided and operated by Silent Falcon UAS Technologies, LLC (Albuquerque, NM) . Bohannan Huston, Inc. (Albuquerque, NM) served as the prime contractor for collection operations for both the rotor-based and UAS collections and created first-level data products (e.g., digital elevation models, contour maps, etc.) from the acquired data.

	Rotor	UAS
Collection Altitude (ft. AGL)	1500	700
Collection time	~1 h	~1.5 h
Collection Area (km^2)	4.3	4.5
Point density (ppsm)	40	400



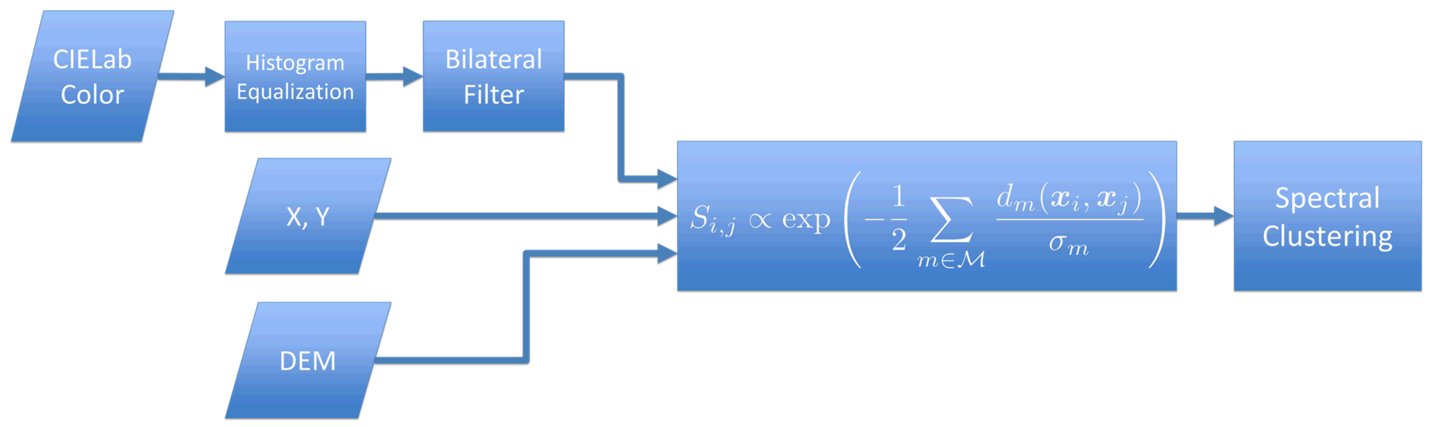




Super-pixel Segmentation

Why Segment?

- Reduce data into logical clusters
- Downstream tasks like classification operate on a super-pixel basis



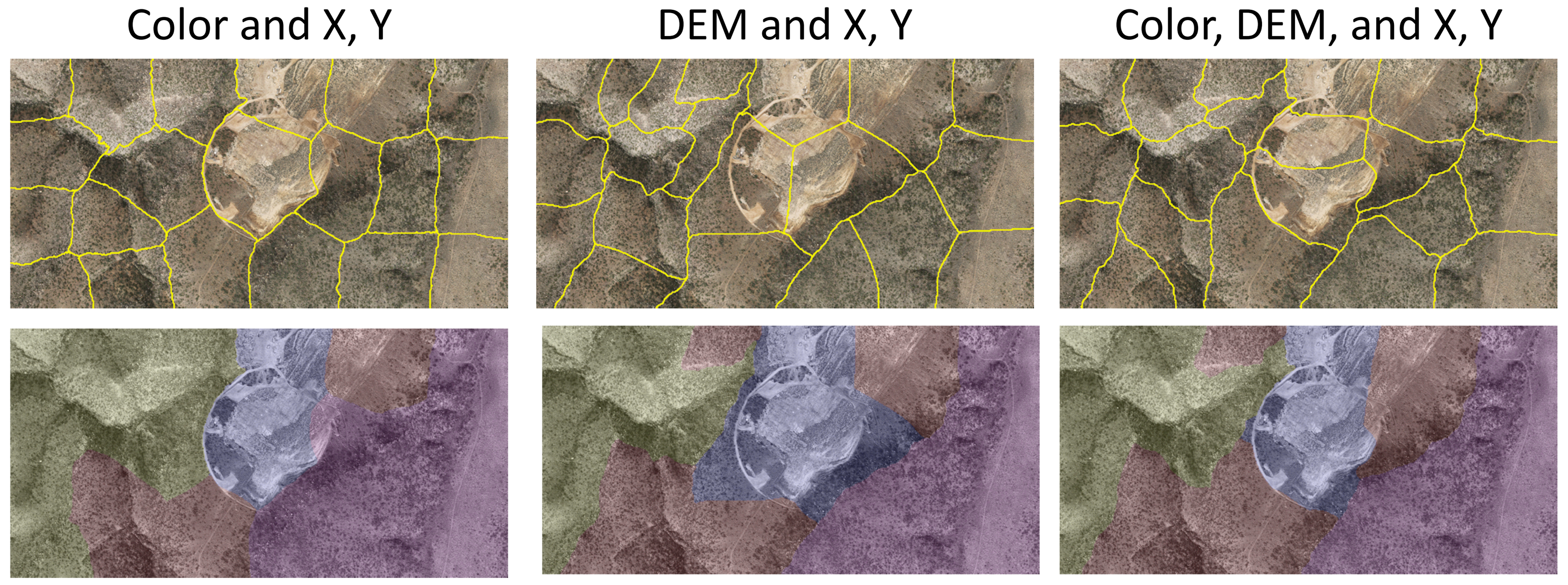
Spectral clustering for different subsets of input features. A simple rule based classifier is applied to the resulting super pixels. Classes are:

- Canyon (yellow)
- Test Site (blue)
- Mesa (purple)
- Unclassified (red)

The canyon and mesa are evident in the DEM but not the RGB and the test site is evident in the RGB but not the DEM.

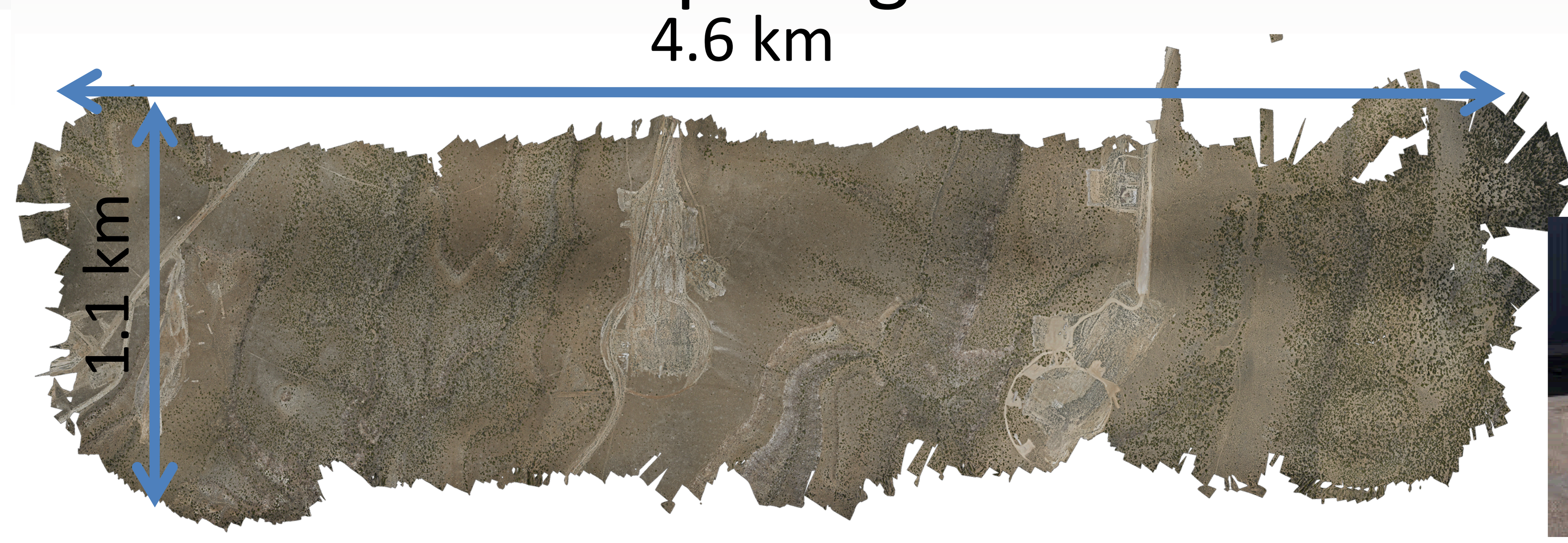
Additional parameters (color and elevation) improve physical interpretability of super pixels.

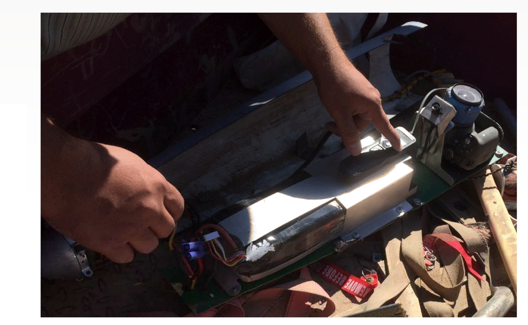
Color and X, Y | DEM and X, Y | Color, DEM, and X, Y



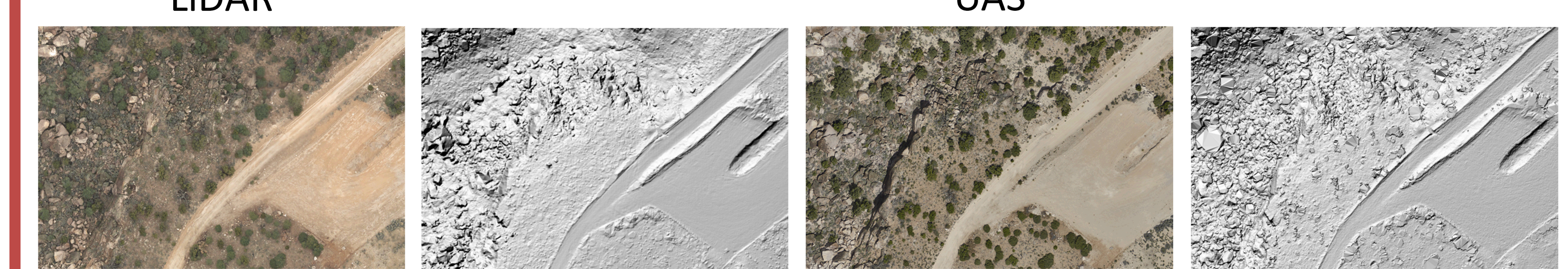
Good on test site, bad on canyon and mesa. | Good on canyon and mesa, bad on test site. | Good on canyon, mesa, and test site.

Comparing UAS and LiDAR

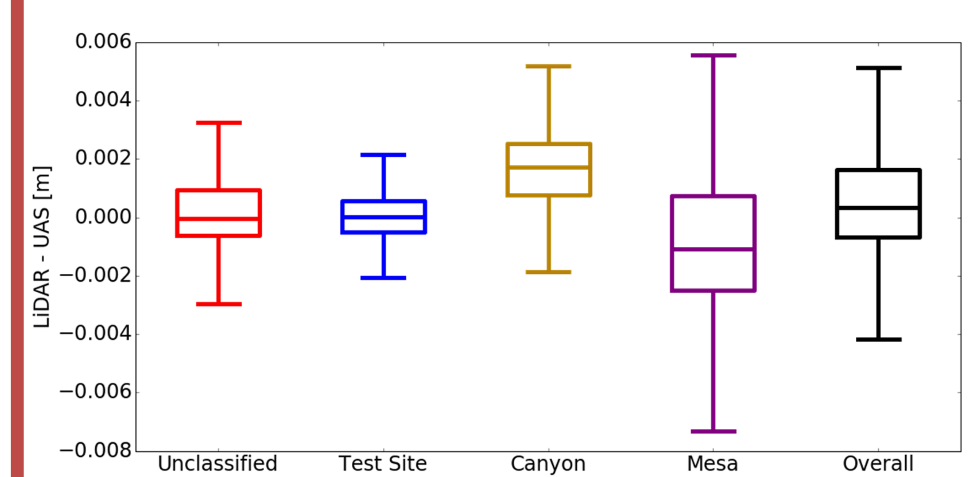




LiDAR | UAS



UAS-based collections give nearly identical results for much lower complexity and cost.



LiDAR DEM – UAS DEM. Colors represent classifications found using Color, DEM, and X, Y.

DEM	Horizontal Accuracy (m)	Vertical Accuracy (m)	GSD (m)
LiDAR	0.072 ± 0.042	0.027 ± 0.014	0.125
UAS	0.203 ± 0.054	0.119 ± 0.02	0.05

LiDAR DEM | UAS DEM | LiDAR – UAS DEM

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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